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FACTORS INFLUENCING THE "SECOND-ATTACK" OF THE DOUGLAS FIR BEETLE -- PROGRESS 1960-1962

by

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SUMMARY

The Douglas fir beetle is sensitive to the moisture content of sapwood when reared in slabs in the laboratory. When the infested slab drops below 85 per cent of the original green weight, or about 90 per cent of ovendry weight, the beetles leave the first gallery and seek fresher material in which to construct a new gallery. In the field, during 1960 and 1962, no definite period of second attack was detected. Rather, the beetles left the first galleries irregularly during the summer. The importance of the second attack in killing standing trees is questioned.

INTRODUCTION

The Douglas fir beetle (Dendroctonus pseudotsugae Hopk.) has one generation per year, with some beetles making more than one egg gallery. The additional egg galleries are commonly referred to as the "second-attack". Atkins and Farris (1962) observed that females establish as many as four galleries in a single summer. The second attack is recorded as occurring from late July through mid-September in western Oregon (McCowan and Rudinsky, 1958). Evenden and Wright (1955)

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reported that the second or summer attack usually occurs in July and August. Walters (1956) stated that in the interior of British Columbia the spring attack occurs from late April to mid-June and the summer attack about six weeks later. Chapman and Kinghorn (1958) found that the peak attack occurs in mid-May at Cowichan Lake, British Columbia, with another smaller one in early July. McMullen and Atkins (1962) report the flight period to be throughout May and June with only sporadic flying populations thereafter. These authors have shown that the principal factor influencing the spring flight period is weather. The beetles will emerge any time after early May if the air temperature reaches 65-70°F. for a few days.

The significance of the second attack is under question. McCowan and Rudinsky (1958) feel that in some years the second attack may be responsible for as much tree mortality as the first. Rudinsky and Vité (1956) have shown that the Douglas fir beetle can bore into the tree faster at the higher temperatures that prevail during the second attack; the accelerated boring rate may help to lower a tree's resistance. Merker and Muller (1951) postulate that trees are more attractive and susceptible during hot, dry weather to attack by bark beetles. Walters (1956) and Furniss (1956) disagree: they judge the second attack to be less intense and more protracted than the first, hence less critical in respect to the infestation of living trees.

One factor influencing the proportion of Douglas fir beetles making a second attack is the intensity of initial attack, according to McMullen and Atkins (1961). They showed that the number of parent beetles remaining in the original galleries decreased sharply as the number of attacks per square foot of log surface increased above five. Reid (1962), working with the mountain pine beetle, demonstrated that the moisture content of the inner bark decides whether or not the parent beetles leave the first gallery: when the moisture content of the inner bark is 100 per cent or less (ovendry basis), the female beetles cease laying eggs. Also they change from flight negative to flight positive after the moisture content of the inner bark reaches this value. McMullen and Atkins (1962) in their cage studies indicated an increased re-emergence of parent beetles following periods of cool weather.

METHODS

All laboratory tests were made in slabs as described by Johnson (1962). In the first series of tests, slabs were dried to obtain the following weights expressed as a per cent of the original green weight of the slab: (1) 65-75, (2) 76-85, (3) 86-95, and (4) 96-100. Each slab was then waxed and

infested with a pair of Douglas fir beetles. Each infested slab was then placed in its own cage along with a fresh slab and kept at room temperature. After three months, the bark was removed from the slabs so that the length of gallery, the number of egg niches, the number and stage of development of progeny, and the presence or absence of parent beetles could be noted.

In a second series of tests, pairs of beetles were placed in fresh slabs, some of which were completely waxed, some partially waxed and others left unwaxed. The slabs were placed in cages with a fresh slab and later studied as described above. In all these laboratory studies, the slabs were examined weekly to determine when the parent beetles first left their original gallery and when they commenced boring in the fresh slab placed in the cage with the original slab.

In the field, a 24-inch d.b.h. Douglas fir was felled on May 1, 1960 in a mediumly stocked stand of 100-year-old trees. Sixteen 3-foot sections were marked off and eight of these were protected by fine-mesh plastic screen (Fig. 1). The screens were manipulated so as to expose to attack some of the sections for the first month, and others for the second, third, or fourth months in turn. All combinations of the four periods of exposure were provided. One section was never exposed and another was exposed for the entire 4-month period. At weekly intervals, the fresh attacks on the exposed sections were counted and marked. At the beginning of each monthly period, a fresh tree was felled and the attacks tallied and marked at weekly intervals. In October 1960, the bark was removed from all sections and the following information recorded: (1) number of attacks per section, (2) number of aborted attacks per section, (3) average length of a gallery on the top, sides, and bottom, (4) number of progeny by stage of development, and (5) number of parent beetles boring exit holes.

RESULTS

Laboratory studies

The moisture content of the sapwood and phloem largely determines how long the parent beetles remained in their galleries. Table 1 shows that the beetles in slabs at 66-75 per cent of green weight constructed galleries that averaged slightly over 1 inch in length. In slabs at 76-85 per cent of green weight, the parent galleries averaged 1.41 inches. The longest galleries occurred in slabs at 86-95 per cent of green weight. The gallery length in the slabs at 86-95 per cent differed significantly from those in slabs at 100 per cent of green weight. This relationship held up throughout the studies using waxed slabs. Slabs cut and waxed immediately

Fig. 1. The above tree was felled on May 1, 1960. Sixteen 3-foot sections were marked off and half of these screened. The screens were manipulated at monthly intervals to determine sequence of attack of the Douglas fir beetle. Entomologist in photo is examining bark removed from one of the sections.

Table 1. Douglas fir beetle parent gallery length (in inches) in slabs dried to various percentages of green weight.

Slab number	Per cent of green weight							
	66 - 75		76 - 85		86 - 95		96 - 100	
	First attack	Second attack[1]	First attack	Second attack	First attack	Second attack	First attack	Second attack
1	2.9	2.0	0.0	14.1	16.4	16.2	16.5	7.6
2	0.0	10.0	1.5	0.0	8.5	0.0	2.7	2.8
3	0.0	17.1	2.2	11.0	28.4	0.0	0.0	6.3
4	0.5	0.0	2.3	15.0	2.6	12.5	16.0	14.0
5	0.0	16.2	1.6	17.0	10.0	3.0	2.0	0.0
6	0.8	19.4	1.0	12.2	1.0	12.2	1.2	1.1
7	2.0	0.0	1.5	0.0	15.0	12.0	12.0	0.0
8	2.5	19.0	1.2	4.0	11.0	0.0	16.0	0.5
Average	1.09	13.95[2]	1.41	12.22	11.8	11.18	8.3	5.38

[1] Second attack slabs were all 100 per cent of green weight at beginning of experiment.

[2] Average computed only from those slabs with second attack.

are often too moist for the beetles, thus exhibiting some of the resistance of an intact tree. If the tree from which experimental material is taken is felled and left for a few days before the slabs are cut, beetle attacks are usually more successful. The decrease in second-attack gallery length by treatment is likely a function of the time available for the parent beetle to construct galleries. The beetles left the low-moisture slabs within a few days and commenced boring in the adjacent fresh slab soon after. But, with two exceptions, they remained in the high-moisture (86-95 per cent) slabs for an average of four weeks before starting a second attack.

When all attacks were started in green slabs, which were caused to dry at differing rates, the galleries were shorter in those slabs whose moisture quickly became critical (Table 2). In this case, however, the parent beetles remained in the initial fast-drying slabs for an average of about three weeks (except the pair in slab no. 6). The beetles, especially the females, did not respond as decisively when faced with gradual drying as they did when placed directly in slabs of low moisture content (Table 1).

Under medium- and fast-drying conditions, the beetles remained in the slabs for about 5 weeks. The female beetles in slabs no. 2 and 6 of the slow-drying series never did leave the first gallery, and X-ray photographs showed that they remained alive for nearly 3 months. Both were dead after $3\frac{1}{2}$ months.

In all but two cases, the females were not accompanied by a male into the second slab. The males usually either died in the first gallery, or left early and perished in the cage. They would not bore into the fresh slab without the female, but would often tunnel under the end of the fresh slab and remain between it and the floor of the cage. The average length of time the males remained in the gallery was 13 days. In any event, the female does not need the male in order to construct the second gallery and lay eggs once she has been inseminated.

The moisture content of the sapwood becomes inadequate for the beetles when it drops much below 90 per cent, ovendry basis. This figure is based on the average moisture content of the entire thickness of sapwood but excludes the phloem. Phloem moisture may remain high long after the sapwood has dropped to a low value (Table 3). Sapwood moisture apparently had little influence on the <u>proportion</u> of beetles leaving the first gallery to make a second attack. Moisture content has a significant effect, however, on the <u>timing</u> of the second attack, the beetles from the drier slabs leaving first.

Table 2. Douglas fir beetle parent gallery length (in inches) in slabs that dried out at different rates.

Slab number	Rate of drying: Fast[1] First attack	Fast[1] Second attack[4]	Medium[2] First attack	Medium[2] Second attack[4]	Slow[3] First attack	Slow[3] Second attack[4]
1	2.9	0.0	22.1	16.2	16.1	12.7
2	2.0	0.0	2.0	0.0	24.0	0.0
3	14.0	8.6	14.0	6.2	15.0	10.5
4	3.0	21.0	15.0	8.0	14.2	12.7
5	1.0	0.0	2.0	0.0	14.5	7.0
6	0.0	17.0	24.0	18.5	28.0	0.0
Average	3.82	15.53[5]	13.18	12.23	18.63	10.73

[1] Slabs not covered with wax.
[2] Slabs 1/2 covered.
[3] Slabs completely waxed.
[4] Second-attack slabs all completely waxed.
[5] Average computed only from those slabs with second attack.

Table 3. Average moisture content (per cent ovendry weight, 70°C., 48 hours) of Douglas fir bark, phloem and sapwood after 2 months compared with freshly cut controls.

Component	Treatment: Completely waxed	1/2 waxed	Not waxed	Freshly cut
Bark	16	20	9	16
Phloem	134	98	15	130
Sapwood	102	33	11	100

Field studies

Field studies in 1960 failed to reveal any definitive period of second attack. Those beetles leaving to make a second attack apparently came out of the galleries off and on throughout the summer months until September, when all attacks ceased. The average number of attacks per 10 square feet of bark surface, in relation to time of exposure to attack, is shown in Figure 2. A high initial attack occurred during the third week of May, coinciding with a rise in air temperature to 68°F. from the mid 40's of the week before. The number of attacks dropped considerably the following week even though air temperatures remained in the high 50's and low 60's.

On the first of June, a second tree was felled and screens were removed from unattacked sections of the first tree. The following week the freshly felled tree was heavily attacked. Attacks actually began within an hour after felling, but were tallied at the end of the week. In the case of the tree cut on May 1, its freshly exposed sections were attacked, whereas those which had already been exposed during May received only a few extra attacks during the month of June. The bars in Figure 2 average the low and high attacks -- i.e., those on freshly exposed sections as well as those on sections exposed to attack previously -- and thus it appears that the fresh sections of the first tree were less attractive than the newly felled tree. Attacks on both trees decreased through the remainder of June.

On the first of July, a third tree was felled. Again, fresh sections of the first tree were exposed. The number of attacks on the new tree and on the fresh sections of the first tree were about equal. Again, however, the attacks were negligible on the sections previously exposed. By the time the fourth tree was felled in August, the first tree had dried out to the extent that even newly exposed sections were no longer attractive. Attacks continued through the third week in August. The tree felled on September 1 was not attacked.

The maximum number of female beetles that could conceivably initiate a second attack was determined by adding the number that had bored exit holes and left the first gallery to the number that might have left the galleries without constructing an exit hole. Of the 959 galleries visible on the bark of the first tree, 778 were found when the bark was removed. Thus about 200 female beetles either had left after boring a short distance into the bark or had died. Of the 778 that bored to the phloem, 587 completed galleries at least one inch long; the remaining 191 galleries were classed as aborted. Of the total number of female beetles reaching the phloem, 230 (or 30 per cent) constructed exit holes and

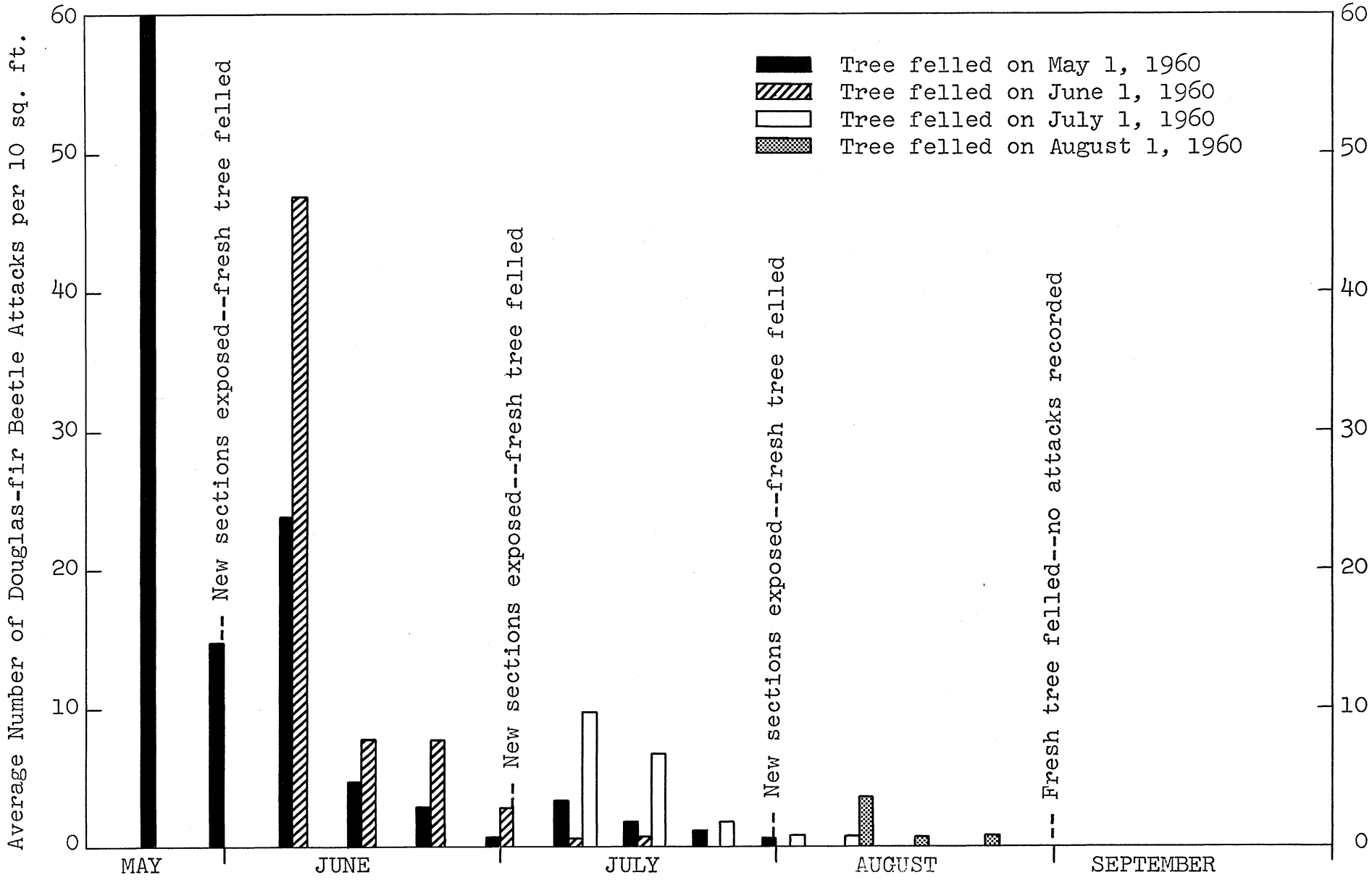

Fig. 2. Average number of Douglas fir beetle attacks per 10 square feet of log surface on freshly exposed log sections and trees felled at various times during the summer of 1960. Height of bar represents the average number of attacks by week.

emerged from the first tree. In addition, 336 galleries with no apparent exit holes were devoid of parent beetles or their remains, indicating that the beetles probably emerged from the entrance tunnel. Very few live parents were found except in the sections exposed later in the year. Those that did not emerge to make a second attack for the most part perished in the first gallery. Of the beetles reaching the phloem, 74 per cent had left, either through an exit hole or through the entrance hole, or were simply missing (sum of row 1 and row 3 of Table 4). The galleries on the top of the log contained proportionally more exit holes than did the galleries on the bottom and sides (5 per cent level of significance); similarly, more female beetles still occupied the galleries on the bottom of the log than those in other positions.

The tree felled in June had 35 per cent of its galleries with exit holes; the July tree had 17 per cent, and the August tree had none. The females attacking the August tree were still laying eggs in late September. It is conceivable that some of them could emerge the following spring and initiate another attack.

In 1962, logs in the same area were stripped of their bark and the galleries examined for emergence holes. At this time, the density of attack averaged 14 per 10 square feet of log surface compared to more than 60 in the highest attacks in 1960. The per cent of the galleries with exit holes averaged 22.

DISCUSSION

The study has shown that the moisture content of the rearing slab was important in determining whether the beetles remain in the first gallery or leave to make a second. The degree to which this is true in the field is yet to be determined. Many factors influence the moisture content of down trees. First of all, we have found a considerable variation in moisture content of the sapwood depending on whether the branches are left on the tree or removed. The time of year of felling is important and so is the degree of shading. All of these factors are influenced by weather. Further field investigation should help in predicting and controlling the number of beetles making second attacks.

During two seasons, we found no concentrated period of second attack; that is, no "second peak". Admittedly, weekly observation of attacks is probably not sensitive enough to pick up small peaks.

The study showed that the recording of attacks on a single tree for a prolonged period is valueless in determining beetle numbers since the tree rapidly loses its attractiveness once attacked. For observation purposes, the felling of fresh

Table 4. Proportion of galleries at various positions on the bole with emerged and nonemerged beetles.

Proportion of galleries that contained:	Position on log				
	Top	East side	West side	Bottom	Average
Exit holes	.37	.26	.29	.26	.29
Female beetles	.14	.23	.26	.40	.26
Neither exit hole or beetles	.49	.51	.45	.34	.45
Total	1.00	1.00	1.00	1.00	1.00

trees periodically throughout the summer is a useful approach. There are, however, other problems. The density of attack on a log depends not only on the number of beetles, but also on the amount of attractive material available. The latter may be much less at the time of second attack than earlier; thus the beetles would tend to concentrate and appear to be more abundant than they actually are. More accurate sampling could be done with flight traps, such as those used by Chapman and Kinghorn (1958), spread at random through the woods.

In a study of Douglas fir beetle attacks on living trees in 1960 (Johnson and Pettinger, 1961), it was apparent that the second attack did little tree killing. Nearly all the attacks on standing trees came with the first large flight of beetles in the spring. Only a few beetles attacked the standing trees later in the year. Whether or not this condition exists during epidemic years is the next step in evaluating the significance of the second attack.

It is realized that in studies with caged beetles, the number of beetles making a second attack might be quite different from that in the field. Some of the beetles leaving the gallery are incapable of flight and would be unable to reach another log or tree. Atkins (1959) demonstrated that the Douglas fir beetle shows considerable variation in its ability to fly after commencing gallery construction. In many females, the wing muscles degenerate when egg laying starts. Some females, however, do not show this effect and, according to Atkins, would be the only ones capable of making a second flight.

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